THE DENTAL PRACTITIONER

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VOL. VIII, No. 12 August, 1958

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THE DENTAL PRACTITIONER
AND DENTAL RECORD

Vol. VIII, *No.* 12 — *August*, 1958

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THE DENTAL PRACTITIONER AND DENTAL RECORD

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EDITORIAL

FLUORIDATION AND ANDOVER

THE announcement of a settlement in the action brought by the Andover Anti-fluoridation Society, who sought a declaration that the practice of putting fluorides in the water-supply was unlawful, is an unfortunate setback for preventive dentistry and preventive medicine as a whole. It must, however, be realized that this was a settlement between the two parties and that this outcome was not decided by a Court of Law. The settlement was achieved by the announcement that the Andover Corporation had withdrawn from the Fluoridation Scheme supported by the Ministry of Health. It seems a tragedy that an important health measure such as this should become a political football on the Local Government stage. Surely such measures should be decided, in the same way as they are controlled, by the Professional Health Authorities or by the Courts of Law. Despite clarification of all doubtful points by a panel of experts at a public meeting in Andover, the anti's have forced the issue, and the newly-elected Corporation has rescinded the decision of the previous Corporation who had made an heroic stand. We sincerely believe that in the long run the people of Andover will regret this action. Superficially it would appear that this Anti-fluoridation Society had a grip on Andover before dental publicity was instigated. Was this a case of poor public relations and of publicity being too little and too late? It would also be interesting to know what stand was taken by the local dental and medical practitioners on this matter. However, it is all too obvious that in future an intensive propaganda programme must be initiated before such measures are put into effect, and the public must be fully informed of the health reasons beforehand. The Health Authorities of this country do not enter into such measures lightly or without expert advice. It is sincerely to be hoped that other authorities, finding themselves in a similar position, will not consider any such negative action without serious and thorough contemplation of the reasons why fluoridation is advocated. It is only right in a democracy that the local people should be given an opportunity to air their views, but it is doubtful whether they have the right to throw out a measure which has already been implemented without further concrete evidence of any deleterious effects. But for the measures recommended by the experts in preventive medicine and adopted by local authorities, this country would still be riddled with the plagues of the Middle Ages and we would still be suffering from typhoid, small-pox, and cholera. It must always be remembered that in the case of dental caries we are dealing with the most prevalent disease in the world and any measure that can reduce it without disturbing the normal metabolism of the body has a right to be implemented for the good of the community.

THE DIMENSIONAL STABILITY OF THREE SILICONE-BASE IMPRESSION MATERIALS

By **J. N. ANDERSON**, M.D.S., L.D.S. (Sheff.)
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HYDROCOLLOID impression materials, of both the reversible and irreversible types, show poor dimensional stability on storage due to their high water content. Both types of material lose water to a dry atmosphere and shrink, and also imbibe water and expand if they are placed in a water-bath. Several reports (Hampson, 1955; Skinner, Cooper, and Beck, 1950; Skinner and Pomés, 1946) have appeared dealing with the dimensional changes on storing hydrocolloid impressions, and all draw the conclusion that impressions in these materials should be cast within a short period of time, usually within ten minutes.

Reports on the dimensional stability of the thiokol materials fall into two categories. In clinical tests (Rosensteil, 1955; Pearson, 1955) the change in dimension of an impression during 24 hours does not appear to be of practical significance, though after storage for one week errors of dimension are noticeable. Laboratory testing (Jørgensen, 1957) reveals a contraction both during and after polymerization.

In certain circumstances it may be necessary to store an impression for a period of time; for example, where laboratory facilities are not available near the dentist's surgery. In addition, there are occasions when duplicate models are required. An impression in a material of suitable elasticity and dimensional stability could be cast several times and thus eliminate the necessity for recording a further impression, or duplication of the master model. In addition, it should be noted that the manufacturers of several silicone-base materials recommend that impressions be kept for 6–24 hours before casting them, in order to produce a satisfactory model surface.

MEASUREMENT OF DIMENSIONAL CHANGES

Dimensional changes in elastic impression materials during a period of storage may be determined in several ways. They may be measured directly by noting the change in the length of a specimen moving freely either in a waxed trough, or, preferably, floating on a mercury bath. The use of a waxed trough to contain the specimen has been applied for many years to determine the setting expansion of dental plasters. Skinner and his associates (Skinner and Kern, 1938; Skinner and Pomés, 1946; Skinner, Cooper, and Beck, 1950) applied this method to the reversible and irreversible hydrocolloids. The mercury bath technique was originally suggested by Docking and Donnison (1948) to measure dimensional changes in investment materials, and later was used by Hampson (1955) and then by Jørgensen (1957) in work on hydrocolloid and thiokol materials respectively.

Criticism may be levelled at these methods that they reveal only the dimensional changes of a freely moving mass of material, and that the results cannot be applied in clinical practice, where the movement of an impression is restricted by the tray.

Other techniques have therefore been used which simulate practical use of the materials. Phillips and Ito (1951), Phillips, Price, and Reinking (1953), and James (1949) recorded impressions of an inlay cavity model, to which a well-fitting inlay had previously been made. The accuracy of fit of this inlay on models made from stored impressions could then be gauged. Phillips and Ito (1951) also noted changes in the relation of markers inserted into the surface of an impression. Skinner, Cooper, and Beck (1950) took impressions of a metal model bearing undercuts, and then made measurements on the resulting stone model after casting the impression. In a later study (Skinner and Hoblit, 1956), the same investigator noted the dimensional changes in impressions taken of an oversize bridge model. The model was one with porcelain teeth in which platinum markers were embedded for reference

points. A round "Invar" peg was used by Thompson (1953) and the resultant plaster model measured by micrometer.

On reviewing the literature, it was felt that one should be able to deduce the direction of the impression material contracts, the impression cavity should become smaller.

To confirm this deduction for the silicone-base materials, their free dimensional changes were measured, and then the effect of these

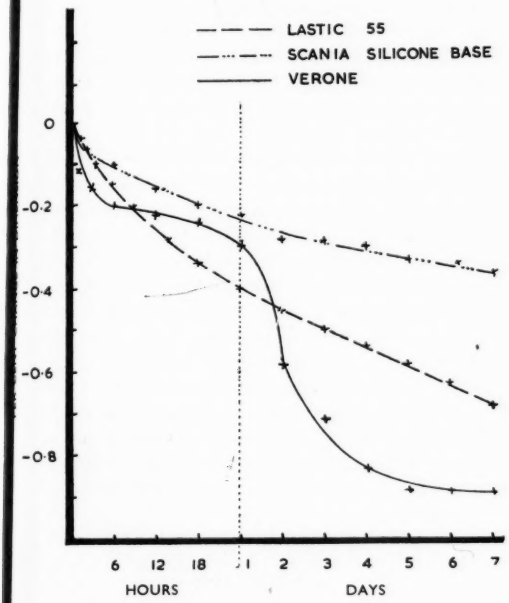

Fig. 1.—Dimensional change of three silicone impression materials in 1–7 days.

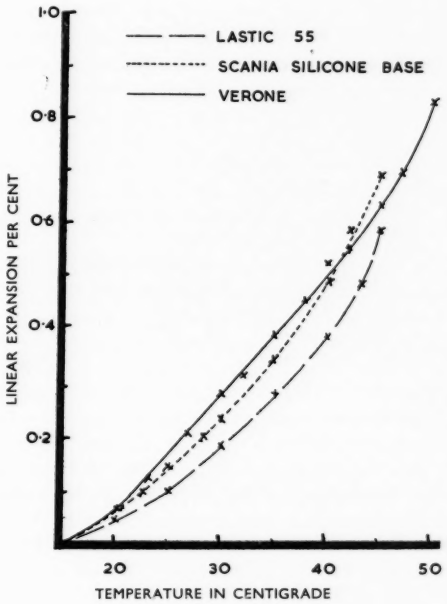

Fig. 2.—Thermal expansion of three silicone impression materials.

any change in the dimensions of an impression if one knew the changes shown in a freely moving specimen. The direction in which shrinkage or expansion takes place is presumably controlled by the support which the impression material enjoys from the tray. Take the example of an impression within a ring or tube of metal. If the impression material contracts, the impression cavity should increase in size if the material adheres to, or is retained mechanically by, the metal ring. If the impression material expands, the cavity should become smaller. James (1949), Phillips and Ito (1951), and Skinner and Hoblit (1956) commented upon this directional shrinkage for hydrocolloid materials. Conversely, in a completely unsupported impression, if changes upon supported and unsupported impressions was recorded.

MEASUREMENT OF FREE DIMENSIONAL CHANGES

The use of a mercury-bath for supporting the material gives accurate evidence of the free dimensional changes. Provided that the specific gravity of the material being tested is low, there is little compression or restriction of its movement from the mercury-bath. The apparatus consists essentially of a perspex bath containing mercury. The specimen is attached to one end of the bath, the other end floating freely. Markers are inserted into the specimen and changes in dimension recorded with a comparator microscope.

The materials tested were:—

Lastic 55,
Scania Silicone-base,
Verone.

A weighed mix of the material to be tested was manipulated into a "sausage" shape and placed on the mercury-bath. One end was attached to the end of the bath, and two markers inserted in the floating portion of the specimen. This activity was completed within three minutes of starting to mix. No measurements were taken until the material had set.

Recordings of length were taken at frequent intervals during the first twelve hours, then at one day, and thereafter at daily intervals, until one week had elapsed.

Unfortunately, it was not possible to maintain at 18° C. the temperature of the room in which this experiment was carried out. Over the weekends, when electricity, gas and central heating were cut off, the temperature fell, often to 12° C. Variations in the readings showed a relation to temperature changes, and therefore the mercury-bath temperature was taken at the time of each reading of the microscope.

In order to correct the recorded length of the specimen for temperature changes, it was necessary to determine the material's thermal expansion and contraction. After the 7 days had elapsed, hot water was run into the mercury-bath until it reached a steady temperature of 50° C. The change in the length of the specimen was then noted as the temperature of the bath fell to a low room temperature, usually about 15° C.

The figures for dimensional change of the specimen with time were then corrected for temperature according to the coefficient of thermal expansion which was determined. Recordings of dimensional change were repeated three times for each material and an average result obtained (*Fig.* 1).

All three materials contracted markedly during the first 6 hours, and then the rate of shrinkage was reduced. The figures for contraction after 24 hours are slightly greater than those reported for the thiokol materials (Jørgensen, 1957).

Graphs of the thermal expansion of the three materials appear in *Fig.* 2. From these the average figures for coefficient of linear expansion (15–40° C.) are:—

Lastic 55	0·00018
Scania S.B.	0·00021
Verone	0·00020

These figures for linear thermal expansion are comparatively high, being twice that given for acrylic resins.

An impression material at room temperature, 18–20° C., will warm approximately to mouth temperature during the 3 or 4 minutes' setting period in the mouth. This will take place rapidly where the material is used in thin sections as the silicone elastomers have good thermal conductivity. After removal from the mouth and cooling to room temperature again, a linear contraction of the order of 0·3 per cent can take place. This contraction is in addition to that shown in *Fig.* 1. The total linear contraction of an impression cast after 24 hours in a plaster mixed with cold tap water could therefore be as high as 0·6 per cent. To reduce the dimensional changes, the impression should be cast in a model material at mouth temperature. This also brings about an improvement in the resulting model surface.

DIMENSIONAL CHANGES IN IMPRESSIONS

In order to discover the practical effects of the supporting medium in controlling the direction of contraction, two experiments were carried out. The first was designed to discover the effect on dimensional changes of the adhesion of silicone-base materials to impression tray materials.

Weighed mixes of each material were placed on pieces of shellac tray material, with and without perforations, and on pieces of stainless steel and nickel-silver. The perforated shellac had 2 mm. diameter holes at 1 cm. spacing. Each support measured 8×3 cm. An impression, 2 mm. thick, was then recorded at 18° C., of a metal ruler bearing centimetre markings. A 5 cm. length appeared on the material over each support. This section was measured by travelling microscope, and changes in dimension noted over a period of three days.

No change in linear dimension was recorded during this period, except with the polished stainless steel support. With this support, however, variable results were obtained, and in only two out of the three materials was a small contraction measured.

At the end of this time, the impression material was carefully removed from its support. In the case of the perforated baseplate, that portion of material passing through the perforations was first cut with a sharp razor. The material was then held at one end of the gauge length and was carefully peeled from the support. Any stretching of the material at this time would, therefore, increase the gauge length. The specimens were placed on a flat surface, and re-measured. A shrinkage smaller in dimension than that recorded in the previous experiment but of wider variation was recorded.

In a second series of experiments, the effects upon the dimensions of an impression were noted.

Impressions of a brass undercut die (*Fig.* 3) were recorded in one material. The impressions were retained in brass rings and were removed with a sharp pull. Each ring was 0·75 in. in diameter and was perforated with holes of the same size, equidistant from each other.

Six impressions were recorded by this method and after 24 hours they were cast in a weighed mix of dental stone at 18° C. The same batch of stone was used throughout the experiments. One hour after casting, the models were measured across the top and base with a vernier microscope. Measurements were taken along two axes at right angles.

A further series of six impressions was recorded under the same conditions, from the same batch of material. These impressions were carefully removed from the ring by cutting away the material in the retention holes. They were left for 24 hours and then cast and measured as before. Results are given in *Table I*.

It will readily be seen that those impressions remaining within a ring show an increase in the size of the die, and therefore of the hole within the impression. This is due to a contraction of the material outwards to its adhesion and retention at the ring. The second group of impressions display a smaller sized die, due to a general contraction inwards of the material.

Experiments in unperforated rings were unsuccessful, as the force required to remove

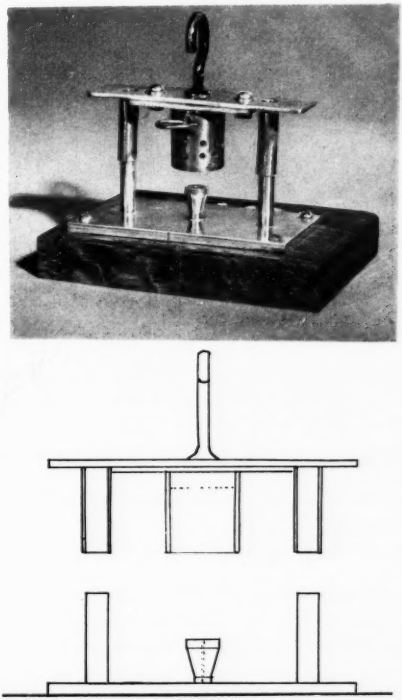

Fig. 3.—Undercut die used for impressions.

the impression caused the material to pull away from the ring.

Similar results were obtained with all three materials tested. It is considered that the method of measuring the models is not sufficiently accurate to allow correlation of these results with those measured on the much longer, freely movable specimen on the mercury bath.

It would appear, therefore, that if a silicone impression enjoys a good and uniform attachment to a ring or tray, the direction of dimensional change of the impression cavity due to a contraction of the impression material can be

deduced from the examination of the shape of the impression. However, where the material is pulled away from the tray on removing the impression from the mouth, varying dimensional errors can be expected.

silicone materials is higher than that of the thiokols.

The effect on changes in dimension of the adhesion of an impression to its tray or support was also noted. Where adhesion between tray and impression was maintained, the material contracted towards the tray. In an impression of a tooth, this would produce an oversize model. When unsupported, the material contracted to a smaller diameter.

Table I.—Dimensions of the Impression Cavity in Supported and Unsupported Specimens

Impression	Top Diameter cm.		Mean Error	Base Diameter cm.		Mean Error
	0°	90°		0°	90°	
			Specimens left in the ring			
A1	0·954	0·948	+0·004	0·526	0·532	+0·008
A2	0·948	0·949	+0·002	0·524	0·528	+0·005
A3	0·946	0·948	correct	0·526	0·528	+0·006
A4	0·950	0·952	+0·004	0·530	0·534	+0·011
A5	0·950	0·944	correct	0·529	0·528	+0·008
A6	0·947	0·949	+0·001	0·528	0·531	+0·009
			Specimens removed from the ring			
A7	0·940	0·938	−0·008	0·512	0·508	−0·011
A8	0·942	0·942	−0·005	0·518	0·518	−0·003
A9	0·942	0·940	−0·006	0·518	0·520	−0·002
A10	0·940	0·942	−0·006	0·512	0·518	−0·006
A11	0·940	0·938	−0·008	0·518	0·520	−0·002
A12	0·942	0·942	−0·005	0·512	0·518	−0·006

EFFECT OF HUMIDITY

A considerable amount of literature exists dealing with dimensional changes of the hydrocolloids with alterations in humidity. It was felt that it would be interesting to note any change in dimension of the silicone-based materials under such conditions.

At the end of the 7-day test of free dimensional changes, the specimens were covered with water at 18° C. and left for 24 hours. Very small dimensional changes were noted; generally a very slight expansion took place, instead of a continuation of the contraction recorded during the previous 7 days.

SUMMARY

Three silicone-base impression materials were tested for free dimensional change on storage. All showed a shrinkage slightly greater than that noted for the thiokol materials. The thermal expansion of the

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THE INTEGUMENT OF THE ENAMEL SURFACE OF THE HUMAN TOOTH

II. THE ACQUIRED ENAMEL CUTICLE

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(*Continued from page* 348)

In Part I of this article the developmental integument of the enamel surface was discussed and it was pointed out that there is disagreement regarding the period of time that the inner layer of Nasmyth's membrane remains on the enamel surface. According to Paul (1896), Stoehr (1910), Lewis (1914), Mummery (1919), Chase (1926), and Atkinson (1950) this membrane is lost shortly after eruption. Choquet (quoted by Dobbs, 1932) considered that it is not present on 88 per cent of erupted teeth and Pincus (1937) states that it remains only in the fissures. The observations of Scott, Kaplan, and Wyckoff (1949), Scott and Wyckoff (1949), and Scott (1952) lend support to these views, by their demonstration of the progressive loss of detail on the enamel surface of erupted teeth as age advances. These authors suggest that this loss is due to wear, and show that a high percentage of the characteristic morphology of the enamel surface of an unerupted tooth is not present within 40 years after eruption, approximately 5 per cent of the loss occurring during the first 10 to 15 years. As would be expected, the loss of detail is more marked in areas of the enamel exposed to wear rather than in the interproximal region, although loss of detail does occur in the latter area, but at a slower rate. However, this evidence has to be reconciled with the fact that a cuticle can be obtained from the enamel surface of an erupted tooth at any age, corroborating the opinion of those, including von Ebner (1922), Walkhoff (1924), Kronfeld (1930), Darling (1943), De Fazio (1947), and Hodson (1949), who consider that Nasmyth's membrane or part of it (e.g., the inner structureless layer or "primary cuticle") remains on the enamel surface throughout life. Approaching the subject from a different aspect, other writers, including Gottlieb (1921 and 1947), Chase (1926), Kronfeld (1930), von Korff (1930), Dobbs (1932), Bibby and Van Huysen (1933), Manly (1943), Vallotton (1945), Atkinson (1950), Erausquin (1951), Turner (1954 a, b), Rushton (1954), and Waerhaug (1956), describe a structure which forms on the enamel surface (and in some instances on the dentine and cementum if these are exposed to the oral cavity) after a tooth erupts. This cuticle has been referred to by different terms and its origin is disputed. For example, Gottlieb described a keratinous "secondary cuticle" which he stated to be a product of the cells of the epithelial attachment and is referred to by other writers as the "attachment cuticle" (Ussing, 1955). Vallotton (1945) referred to a "brown pellicle" and Campaigne and Fosdick (1938) to "mucin plaques", both cuticles being considered to be derived from the saliva. Kirk (1910) held the view that mucin is deposited from the saliva on the tooth surface by lactic acid producing bacteria. Chase (1926) stated that this cuticle formed as a result of the "vital activities of bacteria". Waerhaug (1956) expressed doubt as to the validity of the view that secondary cuticle formation takes place, and states that "until further evidence has been provided to the proof that there really are two cuticles of different consistency and of different origin, it may be wise to use the unspecific term, enamel cuticle".

MATERIALS AND METHODS

After the fixation of extracted human teeth in 10 per cent formal saline or a fixing agent appropriate to a particular histochemical test, extraneous material was removed by scrubbing

the crown surface with a bristle brush using soap or detergent and tap water.

An obvious principal requirement when obtaining a cuticle to investigate its properties is to separate it from the enamel surface with the minimum risk of altering it histologically or chemically, and not to include the "groove protein" of Pincus (1948). "Physical methods", such as scraping the cuticle from the surface (Manly, 1943; Vallotton, 1945; and Gustafson, 1945) or using an air- or water-jet (Pincus, 1937), were found unsatisfactory as only a small amount of damaged material or no material was obtained. After investigation (although the technique is open to criticism) it became evident that a method of obtaining sufficient quantities of apparently undamaged material was that of Pincus (1937) and Atkinson (1950) in which a tooth is immersed in 2 per cent hydrochloric acid and as the superficial enamel is decalcified the cuticle separates from the tooth surface, this process taking approximately 10 minutes. Even after preliminary cleaning some cuticles were found to have stained extraneous material united with them which rendered the cuticle opaque. Such specimens were discarded.

In view of the observations of Scott, Kaplan, and Wykcoff (1949), and Scott and Wykcoff (1949) which show that some of the structural detail of the enamel surface may be lost during the first ten years after the eruption of a tooth, it is reasonable to assume that Nasmyth's membrane may be altered or lost during this period. In order to deduce any difference in properties between the inner layer of Nasmyth's membrane present on the enamel surface of a recently erupted tooth and the cuticle which is similar in appearance and present on teeth later in life, two groups of specimens were collected.

The first group comprised the inner layer of Nasmyth's membrane (primary cuticle) obtained from partly erupted and recently erupted teeth extracted, for example, during the course of orthodontic treatment. (The method whereby this layer was identified is discussed below.) The second group of cuticles was obtained from non-carious "normal" teeth extracted ten years or more after eruption, from patients covering a wide range of ages (16–70 years). The appearance and properties of cuticles from each group were then investigated and compared.

To investigate the possibility of the formation of a cuticle on the enamel surface after eruption, the natural cuticle was removed from a posterior tooth extracted from an adult. The roots were cut off and the crown attached by means of a post to a partial denture. This denture was worn in the mouth for periods varying from 7 to 63 days. To accommodate the bite one cusp of the crown was ground, which exposed the underlying dentine. This had the advantage of making it possible to observe whether a cuticle will form on exposed dentine, although it is not suggested that the dentine surface in this instance is identical with attrited dentine.

The cuticles which were found to form on the denture crown and the naturally occurring cuticles of erupted teeth were examined histologically and histochemically and preliminary studies were made using paper partition chromatography.

RESULTS

It was found that a comparison of the inner layer of Nasmyth's membrane with the cuticle present on the enamel surface of teeth erupted for ten or more years showed dissimilarities when the two cuticles are suspended in water and viewed under a low-power microscope. Both cuticles appear on cursory examination to be structureless transparent laminæ which may be colourless or lightly pigmented. However, it became evident that certain differences exist between them in appearance and properties as follows:—

1. The inner layer of Nasmyth's membrane exhibits interference phenomena, which is the property of a thin lamina to refract light; in contrast the cuticle removed from a tooth erupted several years does not show this property.

2. When unstained spread preparations are viewed under the high-power objective of a microscope, the inner layer of Nasmyth's membrane invariably shows markings which are usually considered to be due to impressions

formed by outcrops of prisms on the enamel surface (the "perikymata", *Fig.* 1), whereas such markings are faint or non-existent on the cuticle of adult teeth. Frequently in older

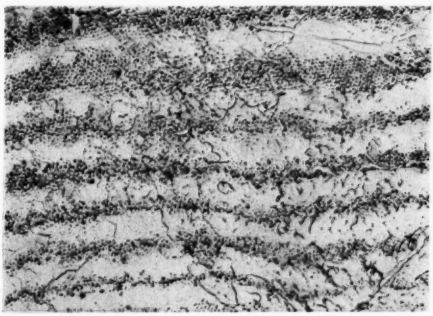

Fig. 1.—Unstained spread preparation of the inner layer of Nasmyth's membrane, showing the impressions made by the enamel prism-ends. (× 60.)

teeth it has been found that the latter cuticle is traversed by lines (*Fig.* 2), presenting a similar picture to celloidin replicas prepared from such teeth by Scott and others. It is suggested that these lines are minute "scratches" resulting from wear on the enamel surface which become filled by cuticle material, giving the cuticle this appearance.

3. The two cuticles show different solubilities and different reactions in acid (*see* p. 376).

4. A difference between the cuticles can be demonstrated using histochemical methods (*see* p. 377).

From these observations it is evident that either the inner layer of Nasmyth's membrane alters as age advances or alternatively it is lost and a cuticle forms on the enamel surface after eruption. Both these views have been suggested previously by different authors.

In support of the argument that a cuticle is formed after eruption, it was found that in many cases, when a tooth showing attrition is placed in 2 per cent hydrochloric acid, a cuticle separates from the attrited enamel surface which is continuous with the cuticle covering the remaining surface of the crown. By way of a control it is simple to demonstrate that if an area of the enamel surface is abraded with a sand-paper disk prior to immersion in acid, a cuticle does not separate from the abraded area. This indicates that a cuticle is formed on the attrited enamel surface, rather

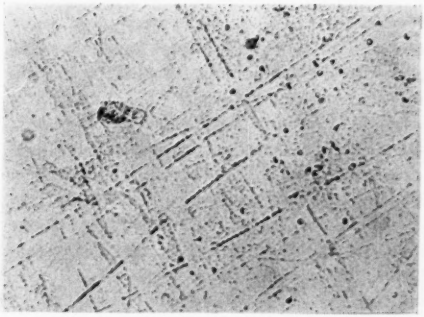

Fig. 2.—Spread preparation of the structureless cuticle removed from the enamel surface of a tooth of a person advanced in age. (Unstained.) (× 60.)

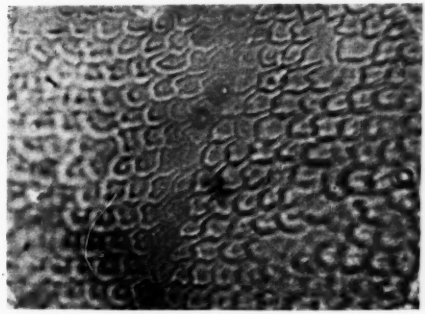

Fig. 3.—Unstained spread preparation of the cuticle formed experimentally on a natural tooth crown. The prism outlines are exaggerated due to etching of the enamel by acid. (× 180.)

than a superficial layer of enamel "dissolving off" in the acid. As a result of this observation experiments were carried out using a natural tooth crown attached to a partial denture. The denture was worn in the mouth for a fixed period of time after which the crown was removed, washed in tap water, and placed in a 2 per cent solution of hydrochloric acid. After several minutes a cuticle separated from the enamel surface as occurs under similar circumstances with an extracted tooth; a cuticle did not separate from the dentine surface. By this method it was found possible to form cuticle after cuticle on the same crown.

the number being limited only by the reduction in enamel area as a result of repeated immersion in the acid used to remove each cuticle. Because the enamel is etched by the acid when the previous cuticle is removed, spread preparations of these "experimental" cuticles showed microscopically the typical morphology of an etched enamel surface (*Fig.* 3). Under a low-power microscope (× 12) these cuticles resemble the cuticle present on the enamel surface of adult erupted teeth. If the period of wear is less than 12 days, a cuticle separates from the surface which appears normal under the low-power microscope, but is unstable in 2 per cent hydrochloric acid. In this connexion it should be mentioned that the naturally occurring cuticle obtained from areas of enamel attrition sometimes showed a similar reaction. A few minutes after such a cuticle was removed it dissolved slowly in acid. This reaction is discussed below in further detail.

An attempt was made to assess the origin and properties of this cuticle which forms after eruption. For convenience it will be termed the "post-eruption cuticle" in this communication.

THE BEHAVIOUR OF THE CUTICLES TOWARDS INORGANIC SOLVENTS

The reactions of the inner layer of Nasmyth's membrane and the post-eruption cuticle were observed and compared when several cuticles from each group were placed in water at different temperatures and in hydrochloric acid and sodium hydroxide solutions for 24 hours at different temperatures and concentrations which varied from N/100 to 10N. The results are shown in *Table I*, from which it is evident that the inner layer of Nasmyth's membrane shows a variable reaction, whereas the post-eruption cuticle is insoluble at room temperature in all concentrations of acid. At the same time, the latter cuticle becomes a mauve colour after immersion in the acid. This colour change, together with relative insolubility in acid, serves as a further distinguishing property between the post-eruption cuticle and the inner layer of Nasmyth's membrane.

Generally speaking it can be said that the inner layer of Nasmyth's membrane is insoluble in weak acid, dissolves in strong acid, but between these two extremes the reaction is inconsistent. It was stated in the previous article, in agreement with many writers, that this cuticle appears to be a final layer of enamel matrix. In view of the fact that the cuticle may or may not be calcified this constitution may alter from one tooth to another. Where it is uncalcified it will resemble uncalcified enamel matrix and be relatively insoluble, whereas in teeth where it is partly or completely calcified it will be soluble in acid. This accords with observations on the staining properties of this layer which were described previously.

Table I.—The Reaction of the Cuticles in Inorganic Solvents

HCl	Inner Layer of Nasmyth's Membrane		Post-eruption Cuticle
10 N to 5 N	Room temp.	Dissolved	Insoluble
	100° C.	Dissolved	Dissolved
5 N to 2·5 N	Room temp.	Dissolved or fragile	Insoluble
	100° C.	Dissolved	Fragile
2·5 N to $\frac{N}{5}$	Room temp.	Inconsistent reaction	Insoluble
	100° C.	Dissolved or fragile	Fragile
$\frac{N}{50}$ to $\frac{N}{100}$	Room temp.	Insoluble	Insoluble
	No colour changes observed.		Colour changes Brown—maroon —mauve

Neither cuticle showed any change in alkaline solutions at room temperature. At boiling point some specimens became fragile but did not go into solution. Similarly the cuticles did not show any change in water, either at room temperature or at 100° C.

CHEMICAL CONSTITUTION

A biochemical study of the enamel cuticles has been carried out previously by Rosse (1921), Stein, Hinck, and Hoskins (1928), Manly (1943), Vallotton (1943, 1945), and Pincus (1948).

When applying histochemical techniques to examine the post-eruption cuticle it is necessary to exercise meticulous care only to use specimens which appear to be entirely free from extraneous material, otherwise the results are misleading and unreliable.

According to French and Edsall (1945) and Hawk, Oser, and Summerson (1947) formaldehyde can react with a number of functional groups present in proteins. On account of this the ninhydrin reaction was applied directly to fresh unfixed specimens, which gave a negative result. As the specimens were small and thin an alternative method was evolved to apply this test. Several cuticles were hydrolysed in concentrated hydrochloric acid for 15–24 hours at 100° C. The hydrolysate was evaporated to dryness under reduced pressure and the acid was replaced by distilled water. A drop of this solution was absorbed on to a piece of filter-paper and allowed to dry. When the areas were sprayed with a 0·1 per cent alcoholic solution of ninhydrin and the paper warmed over a Bunsen burner flame, a violet colour developed, indicating a positive reaction. A positive result was obtained on applying the Millon and xanthoproteic reaction and the Biuret test, giving evidence of the presence of amino-acids and peptide linkages from which it was concluded that protein is present in this cuticle.

A relatively large volume of humin is formed when several cuticles are hydrolysed in strong acid. Humin is a dark brown insoluble precipitate which forms when a combination of carbohydrate and protein is hydrolysed in acid (Gortner and Blisch, 1915; Roxas, 1916; and Lugg, 1938), this reaction being referred to sometimes as the Maillard reaction. As the presence of protein has been demonstrated already, such a reaction indicates that carbohydrate is also present in the cuticle. This was found to be so, a positive result being obtained with the thymol test, Benedict's reagent, and Feigl's test, using silver nitrate paper. It has been suggested previously that the post-eruption cuticle is derived from salivary mucin, this substance being a carbohydrate–protein complex.

The literature concerning salivary mucin has been critically surveyed by Clement (1951) and the chemistry of mucopolysaccharides is discussed by Stacey (1946). The behaviour and properties of mucosubstances are described by Kent and Waterhouse (1955).

Histochemical tests were then applied to spread preparations of the cuticle to investigate the combination between carbohydrate and protein shown to be present. The cuticle becomes a red colour when it is stained by the PAS method, indicating the presence of a neutral mucopolysaccharide or mucoprotein. The intensity of the colour produced is some indication of the group to which the tissue belongs (Pearse, 1953). The inner layer of Nasmyth's membrane gives a negative result with this reaction.

Specimens of the post-eruption cuticle and the inner layer of Nasmyth's membrane were fixed in a 16 per cent formalin solution containing 8 per cent lead acetate and stained with toluidine blue using Lison's method (1936). Only the post-eruption cuticle stained metachromatically, becoming a purple-violet colour, indicating a neutral mucopolysaccharide or mucoprotein (Pearse, 1953).

A preliminary study employing paper partition chromatography demonstrated the presence of aspartic acid, glutamic acid, serine, glycine, and alanine. As these amino-acids are present in many proteins this information cannot be regarded as significant. It would be expected that tyrosine would be demonstrated in view of the results obtained with the Millon and xanthoproteic tests. However, it may be that the tyrosine was destroyed during the preparation of the hydrolysate.

The histochemical tests, already described, indicate that the post-eruption cuticle is a mucoprotein or mucopolysaccharide. From this it follows that it may be derived from the mucin of saliva, as suggested by Kirk (1910),

Dobbs (1932), Campaigne and Fosdick (1938), Manly (1943), and Vallotton (1945).

Assuming this thesis to be correct, the question arises as to the mechanism whereby the cuticle is formed on the enamel surface. It was found in a further investigation that an apparently similar cuticle can be formed *in vitro* under sterile conditions on the enamel surface of teeth from which the naturally occurring cuticle has been removed, which

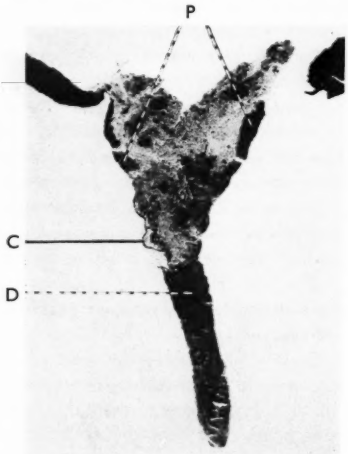

Fig. 4.—Section through an occlusal fissure showing part of the cuticle which covers the surface (C). P, Plaque material. D, Debris in the fissure. (H. and E.) (× 60.)

indicates that bacteria do not take part in the process. According to von Korff (1930) mucin is adsorbed on to the enamel surface. Little (1954) states that observations using the electron microscope confirm this point of view. Further work on the problem is necessary before a final conclusion can be obtained.

THE RELATIONSHIP OF THE POST-ERUPTION CUTICLE TO THE ENAMEL SURFACE

The most important connexion of the post-eruption cuticle is its continuity with crack lamellæ (Bodecker and others, 1951; Atkinson and Prophet, 1953). This continuity can be demonstrated readily by immersing a tooth in weak acid and examining the cuticles under a dissecting microscope 24 hours later.

It can be seen in sections of fissures and tubular hypoplastic pits that the cells of Nasmyth's membrane degenerate. Debris appears to collect in such areas but invariably a cuticle can be identified covering the enamel surface (*Fig.* 4). It was not possible to isolate specimens of the cuticle alone from fissures without extraneous material being

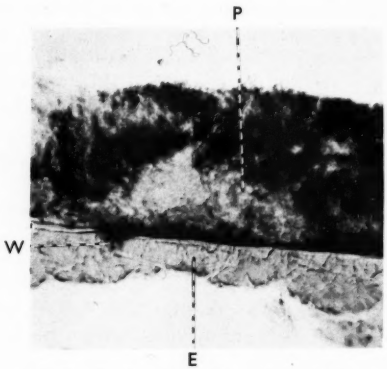

Fig. 5.—Section through a plaque (P) on the enamel surface showing the plaque material filling a "wedge" depression (W). E, Enamel. (Gram's stain.) (× 300.)

included. Similarly the cells of Nasmyth's membrane disappear from the wedge-shaped depressions on the enamel surface. Again in such situations a cuticle can be identified. As described by Hodson (1953) these wedge-shaped areas appear to become filled with plaque material (*Fig.* 5), a fact which may be of significance in early enamel caries.

OTHER SECONDARY CUTICLES

A discussion of the enamel integuments is incomplete if no account is given of the "secondary horny cuticle" originally described by Gottlieb (1921). The existence of such a structure is widely accepted, although some authors doubt this (Hodson, 1949; Waerhaug, 1956). First, it is necessary to indicate how the secondary cuticle can be distinguished from the primary cuticle and the post-eruption cuticle. The most striking difference

is its much greater thickness, which is evident on examining sections of the secondary cuticle. Also this cuticle was found in some instances to contain birefringent substances (*Fig.* 6).

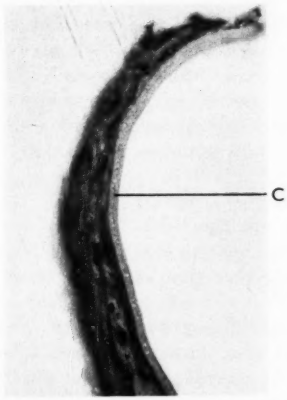

Fig. 6.—Section of Gottlieb's secondary cuticle (C) viewed by polarized light (using a gypsum plate), showing the birefringent contents which give the cuticle a granular appearance. (H. and E.) (× 300.)

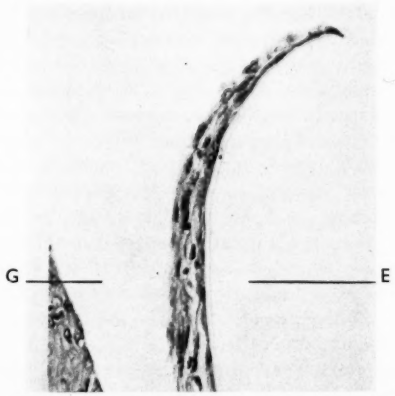

Fig. 7.—Section shows Gottlieb's secondary cuticle in the gingival crevice region with normal nucleated epithelial cells lying adjacent to the cuticle. G, Gingival crevice. E, Space occupied by the enamel. (H. and E.) (× 180.)

The birefringence was usually, but not always, found in that part of the cuticle which was nearest to the oral cavity, and may be due to foreign body material which becomes included in it and may be of significance in early calculus formation. Where the birefringence occurs the cuticle has a "granular" appearance when viewed in transmitted light. The secondary cuticle was found in sections of erupted human teeth only where the adjacent soft tissue was in situ around a tooth, and then not in all such specimens (although it should be pointed out that Gottlieb inferred that this cuticle is not always present). This cuticle was never identified in sections of cuticles removed from the free enamel surface. However, in longitudinal sections of the secondary cuticle in situ with the epithelial attachment it can usually be seen extending to the cervical region of the clinical crown, which suggests that the cuticle remains confined to the gingival sulcus and its immediate vicinity.

Gottlieb considered the secondary cuticle to be composed of keratin elaborated by the cells of the epithelial attachment. It is difficult to understand how this keratin is produced, as the epithelial cells adjacent to the cuticle appear to be unchanged from the

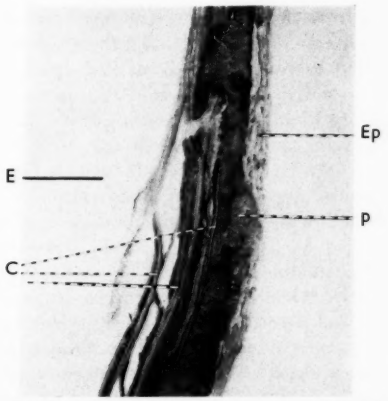

Fig. 8.—Human. Section showing a laminated cuticle (removed from the gingival crevice area), similar to that described by Rushton as occurring in the hamster. Ep, Epithelial cells from the crevicular epithelium. P, Bacterial plaque. C, Layers of cuticle separated by plaque material. E, Space occupied by the enamel. (H. and E.) (× 300.)

deeper cells and there is a sharp junction between the cells and cuticle in contrast with epidermis, for example (*Fig.* 7). The thickness

appears regular and the structure amorphous, or granular and striated at right angles to its length, unlike keratin layers elsewhere which are often irregular in thickness and somewhat "scaly" in appearance. Furthermore, the cuticle does not readily stain or react similarly to keratin with commonly used stains such as hæmatoxylin and eosin and Mallory's stain. Quite apart from this evidence it is generally accepted that physical stimulation of an epithelial surface is an important factor in keratin formation, and it is doubtful if such stimulation exists in the situation where the secondary cuticle is found. Trott (1957) did not find evidence of keratinization of this crevicular epithelium in his study of the gingival epithelium.

The acquired enamel cuticle described by Rushton (1954) as occurring in hamsters must also be mentioned. Such a thick, laminated, yellowish, non-birefringent cuticle can be seen associated with human teeth (*Fig.* 8), but its presence appears to be confined to stagnation areas where there is plaque material and to carious teeth. As this type of cuticle has been found to occur only in the pre-carious or carious state it was considered that it could be included better in a study of the significance of the cuticles in relation to caries, and therefore it was not included to any extent in the present study. The areas covered by this cuticle are relatively small and it has a segmented appearance in cross-section.

Both Gottlieb's secondary cuticle and that described by Rushton give a positive result with a modified Gomori's aldehyde fuchsin method. As a control, sections of mucous gland and keratinized oral mucous membrane were stained under identical conditions using the same batch of solutions; the former gave a positive result and the latter was negative, which demonstrates that the cuticles under discussion are not composed of keratin and may well be mucinous in origin. However, it was found that they do not show the reaction given by mucinous material when stained by Schiff's method, or with Toluidine blue, Celestin blue, Alcian blue, and Mucicarmine (sections of gastric mucous tissue being used as a control in each case). It is hoped to explain this contradictory behaviour after investigation of age changes in the cuticles.

In human teeth both cuticles are present, mainly in sheltered areas rather than the free enamel surface and in intimate association with other structures (epithelium or plaque), which adds difficulty to their investigation as they cannot be isolated for analysis in the way that was possible with the primary cuticle and post-eruption cuticle. Further work on these cuticles is in progress.

DISCUSSION

Although the work described is concerned with the integument of the "free" enamel surface rather than the fissures, it is appreciated that the latter are of first importance when considering dental caries. However, it was felt that an attempt should be made to clarify in general terms the conflict of opinion regarding the formation and nature of the enamel cuticles. Authors differ in their views of the significance of the cuticles when considering dental caries or the solubility of surface enamel in acid; some even ignore them.

The mechanism whereby the post-eruption cuticle forms is not understood. It is not apparently the result of a simple deposition of mucin because the cuticle is often found to be relatively soluble in acid where it is removed from areas of constant wear, but very resistant when obtained from the "free" enamel surface. This resistance cannot be explained by suggesting that on the "free" surface the cuticle becomes greatly increased in thickness because this does not appear to be so and there is a limit to the thickness attained. The change appears to be in the composition of the cuticle itself.

In spite of the conflicting results obtained in a preliminary examination of Gottlieb's secondary cuticle and the laminated cuticle similar to that described by Rushton, the writer is inclined to the view that the secondary cuticle and the laminated cuticle originate from the same source as the post-eruption cuticle and that all three cuticles are a modification of the same structure. In this connexion it is interesting to note that following the mechanical removal of the

secondary cuticle from the gingival pockets of experimental animals, Waerhaug (1956) found that on subsequent investigation the cuticle re-formed after a period of time. From this Waerhaug concluded that the cells of the epithelial cuff re-formed the cuticle. This observation could also be interpreted to suggest that the cuticle was formed in the same way as that on a denture crown experimentally, as described above. That this cuticle and the laminated cuticle are thicker could be explained by the fact that both cuticles form in sheltered areas, which accords with the observation already discussed that the thick secondary cuticle is not found on the free enamel surface, except in the gingival region.

A study of the literature describing the protection and resistance of the enamel surface to caries or acid solution gives an indication of the possible significance of the post-eruption cuticle. Of particular interest in this respect is the work of Darling (1943), who found experimentally that the enamel of erupted teeth possesses a cortical protection against artificial caries and dilute acid except where there is natural or artificial abrasion or attrition; this observation accords with the writer's finding described above that the post-eruption cuticle recovered from such areas is relatively soluble in acid. Walsh and Green (1950), who demonstrated that the enamel surface can be protected by an adsorbed film of a long chain amine, observed that prior to their experiments the application of sticky wax to the enamel surface and its removal with carbon tetrachloride in some way alters the solubility of the surface enamel in acid attack. It is tempting to suggest that the post-eruption cuticle was removed in the process of applying and dissolving off the sticky wax, thus allowing the enamel to be more readily dissolved by the acid.

It has been demonstrated by Manley and Hardwick (1952) that in enamel caries the affected enamel matrix is rendered resistant to acid, and these authors state that "mainly muco-protein" from the saliva is "absorbed onto" the porous enamel. It follows that such substances may be similar to those composing the "post-eruption cuticle" and may also occupy faults in the enamel to form "crack" lamellæ (Atkinson and Prophet, 1953).

SUMMARY

Evidence is presented in this and the previous communication indicating that Nasmyth's membrane is composed of an outer cellular layer which is removed by the trauma of mastication shortly after eruption and an inner structureless layer which remains for several years after eruption. The presence is demonstrated of a cuticle which appears to be derived from saliva, and termed the post-eruption cuticle. A study of the composition and properties of these cuticles is described.

Acknowledgements.—The writer wishes to thank Professor R. Dennell, Professor of Experimental Zoology, University of Manchester, for his invaluable advice and assistance and for providing the facilities of his department where much of the work was carried out. Also Professor H. G. Radden for his interest in the work and the histology laboratory technicians of the Turner Dental School for their assistance.

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USE OF AN ALUMINIUM CASTING ALLOY FOR CONSTRUCTING DENTURE BASES

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ALUMINIUM is obtained by electrolytic reduction from its oxides and silicates and the resultant metal is a commercial grade of aluminium containing up to 1 per cent of impurities. By a further electrolytic refining process the metal may be obtained with only 0·01 per cent of impurities and in this form is known as "super purity aluminium". This is very resistant to corrosion and is capable of producing a highly reflective surface but it is soft and lacking in strength. These properties may to some extent be modified by alloying with other elements.

The use of "super purity aluminium" for construction of bases for full upper dentures has been advocated on several occasions. Campbell (1935) described a technique in which the material was first cast and subsequently swaged and the following year described the use of an alloy of super purity aluminium with 3 per cent magnesium for construction of bases by casting alone. Sizeland-Coe (1951) advocated the use of a similar alloy in the wrought form by swaging or pressing and suggested that this material was suitable for limited use as a partial denture base material. Tregarthen (1944, 1949) who used both the casting and swaging methods did not state the type of alloy he used but he described in detail the method of anodizing the prepared base.

Whilst the most enthusiastic advocate of the use of aluminium alloys could not claim that they are ideal as materials for the construction of denture bases, there are occasions when they may be employed for this purpose with advantage.

Since many practitioners may be unfamiliar with the use of these alloys it is proposed to give details of a suitable casting alloy and after comparing its properties with those of other denture-base materials to discuss indications for its use. This will be followed by a consideration of the particular problems associated with the casting of this type of alloy and details of the method employed in processing and finishing denture bases in this material.

The metal which has been used successfully in this department over the past two years is an alloy, not of the super purity type, but of

the commercial grade of aluminium containing 5 per cent magnesium and conforming to the specification LM 5. Its cost is approximately 1½*d.* oz. which compensates to some degree for the expense involved in fabricating a metal base.

Table I

	Aluminium Alloy	Acrylic Resin	Chrome-cobalt Alloy	Gold Alloy
Density	2·66	1·18	8·2–8·6	15
Hardness (Brinell)	60–68	23–29	280	softened 138 hardened 210
Ultimate tensile strength (tons per sq. in.)	9·6	3	49	softened 26 hardened 49
Melting range (°C.)	580–640	—	1270–1305	870–985
Percentage elongation	4	—	5	softened 4–25 hardened 1–6

1076°F – 1184°F

Table I shows the approximate physical properties of this alloy together with those of other denture base materials for comparison.

Whilst it will be seen that the aluminium alloy is inferior in strength to the other metallic bases it is three times stronger than acrylic resin and if used only for plate types of construction gives excellent results.

In hardness it is again inferior to the other metals used in denture construction but it is more than twice as hard as acrylic in the cast state, takes a higher polish, and irregularities can be removed from the fit surface without destroying its close adaptation to the tissues. Both strength and hardness are increased by the anodic film which may be imparted to this material.

With regard to weight the aluminium alloy is by far the lightest of the metallic bases. Allowing for the thinner section of the palate a denture cast in this material approximates closely in weight to one constructed entirely of acrylic resin.

In addition this alloy has a high thermal conductivity (0·4 c.g.s.) and is resistant to corrosion in the anodized state (*see* p. 384).

INDICATIONS FOR THE USE OF THE CAST-ALUMINIUM ALLOY

This material is capable of fabrication by casting into partial dentures of limited design. Although these alloys are not sufficiently strong to permit their use in a skeleton construction they are strong enough to be used in the form of plates.

There are, however, two outstanding objections to the use of these materials in the partially edentulous case.

1. The possibility of amalgamation between the aluminium of the base and the mercury from new dental restorations. This affinity of

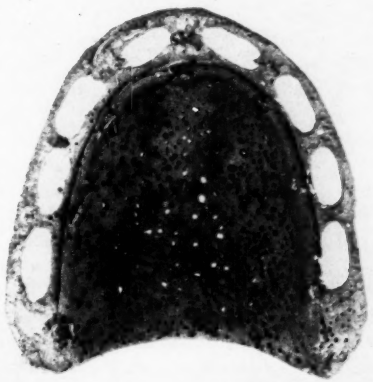

Fig. 1.—A defective casting caused through failure to use a satisfactory flux.

aluminium for mercury results in a peculiar filamentous growth of aluminium oxide on the metal.

2. Electro-chemical corrosion of the base material in the presence of gold and amalgam fillings. Whilst anodizing affords a high degree of protection against both chemical and electro-chemical dissolution the smallest defect in this oxide layer results in quite a considerable electrical potential being developed

between the exposed metal and any gold or amalgam restoration with which it comes into contact.

This can be readily demonstrated by placing a specimen of wrought gold wire and a strip of anodized aluminium in contact with each other in a solution of artificial saliva and connecting them together through a high-impedance volt meter. If the aluminium specimen has been well anodized no potential difference will be recorded but if now the surface layer of this specimen is stoned away and the electrodes are brought together again a marked potential difference will be recorded.

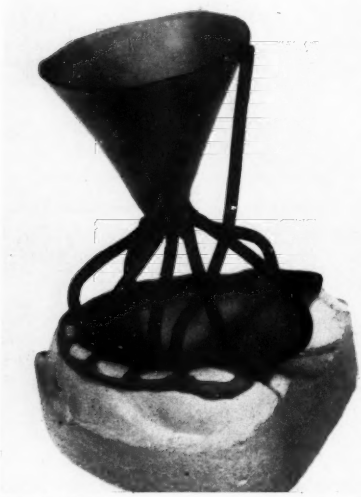

Fig. 2.—Pattern waxed-up on investment model showing the distribution of sprues (a riser is attached at the centre of the palate to improve the flow of the molten metal).

Minor deficiencies in the protective anodic film will render the alloy more susceptible to attack by chemical agents but under normal mouth conditions the base material remains unaffected by corrosion even when it has been necessary to destroy part of the oxide layer in easing a denture.

In view of the foregoing it is necessary to restrict the use of aluminium alloys to edentulous mouths, and they are used to best advantage in the construction of full upper dentures where a metal base is indicated but retentive factors are unfavourable.

PROBLEMS ASSOCIATED WITH CASTING AND DETAILS OF CASTING TECHNIQUE

The casting of aluminium alloys, particularly those containing high proportions of magnesium, calls for special care. Mishandling of the material and faulty technique may result in gross casting defects (*Fig.* 1). In addition to the common oxidation difficulties there is the problem of molten gas inclusion, particularly hydrogen, which may be liberated by the reaction of the magnesium in the alloy with any residual water contained in the refractory crucible. Aluminium alloys are also susceptible to grain growth.

To deal with these problems low-fusing fluxes comprising mainly fluorides and chlorides of magnesium and potassium are used and a grain-refining agent is employed which also cleanses the molten metal of metallic oxides and non-metallic inclusions.

Because of the fluidity of the low-fusing fluxes care must be taken to prevent them being included in the metal during casting. This is accomplished by the use of a "drossing-off" compound—a dry flux which forms a skin on the surface of the molten metal and is applied just before casting.*

Although the co-efficient of expansion of this alloy is high its melting temperature is lower than that of gold and it has been found that accurate castings may be obtained using a proprietary gypsum bound cristobalite refractory.

After the master model has been prepared by the incorporation of a post-dam area and by relieving when and where necessary, a duplicate model is prepared in this refractory and a wax pattern of the base is laid down. The thickness of the wax may be varied according to the strength required in the final casting. For a flat palate one layer each of No. 8 and No. 5 waxes may be used, whilst a V-shaped palate with well-pronounced rugæ

* The fluxes used are supplied by Foundry Services Ltd., and will be referred to by their proprietary names in the description of the casting process.

will probably be strong enough if cast in a single thickness of No. 8 wax. Retention tags and a palatal finishing line are added and the case is then ready for sprueing; the sprues are formed from round wax of 2·5 mm. diameter and these are attached as shown in *Fig.* 2.

Investment is completed in a suitable-sized casting-ring, and, after drying out, the mould is heated to eliminate the wax in the usual manner.

For dental purposes it is necessary to use a centrifugal casting technique as in both air- and steam-pressure methods gas inclusion is likely to occur.

In view of the low specific gravity of the alloy it is necessary to employ a high initial velocity to the centrifugal machine to achieve a satisfactory casting pressure and so, prior to heating the mould, the casting machine should be suitably adjusted.

The heated investment mould should be removed from the furnace and placed into position on the carriage of the casting machine whilst the sprue hole is glowing red. This allows adequate time for the mould to cool to its correct temperature whilst the alloy is being prepared.

A dry crucible is charged with an ingot of the alloy approximately 45 g. in weight and this is heated in an open furnace. Before fusion takes place the surface of the metal is covered with a powdered flux known as Coveral 65. The metal is now gently heated with the reducing flame of a gas-air blow-pipe in order to get the mass fluid. Care should be taken not to disturb the metal surface. (Unlike gold alloys this metal should not be spun.)

Into this molten metal is now plunged 0·5 g. of the grain refining agent (Degaser 190) and this is held in place until all reaction is complete. This is followed by the addition of the drossing-off compound (Coveral 11), which should be sprinkled over the surface of the melt and stirred into the metal. The crucible containing the molten metal should now be carefully transferred to the casting machine and when in place casting should be effected without delay.

After casting, the ring and its contents should be bench-cooled before dis-investing.

MECHANICAL FINISHING AND ANODIZING OF THE CASTING

One of the sprues is left when the plate is separated from the remainder of the casting in order that the base may be totally immersed in the cleansing and sealing solutions and that a satisfactory electrical contact may be made between the metal and the anode clamp outside the electrolyte.

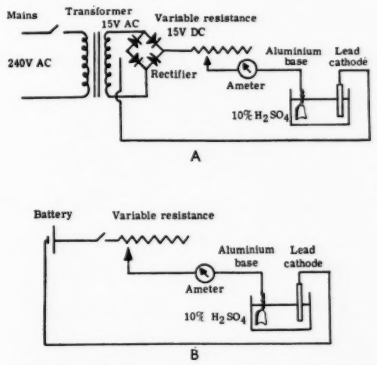

Fig. 3.—Diagrams of the circuit of the anodizing apparatus. A, Using mains current supply; B, Using a 12-volt battery.

After shot-blasting the metal surface is mechanically finished by means of stones and polished with pumice and whitening and metal polish. The polished base is now rinsed under a running tap and scrubbed with a soft brush and detergent powder to remove all traces of abrasive materials. It is next immersed in carbon tetrachloride for 2 minutes to remove any grease attaching to it. Between this and each of the subsequent chemical immersions the specimen should be rinsed in distilled water.

In order to render the surface chemically clean and thus susceptible to electrolytic activity, the base is immersed in a 5 per cent solution of sodium hydroxide for one minute and any excess of the alkali remaining is neutralized by rinsing in 10 per cent nitric acid for a further minute.

The specimen is now made the anode in an electrolytic bath in which the electrolyte is a 10 per cent solution of sulphuric acid and the cathode is formed by a pair of lead or carbon rods.

A direct current is supplied through a combined transformer-rectifier (or alternatively a 6-volt or 12-volt car battery may be used) and this is adjusted so that the current density is about 50 milliamperes per square inch. At this rate the anodizing process takes 45 minutes.

Fig. 4.—A completed case.

The solution is initially at room temperature and there is a small rise in the temperature of the electrolyte which occurs during anodizing. The apparatus used is essentially the same as that commonly employed for copper-plating inlay impressions, and the circuit diagrams are shown for both mains and battery activated equipment (*Fig.* 3).

When this process is complete the specimen is removed from the circuit, washed and boiled in distilled water for 10–15 minutes in order to seal the protective layer. At this stage the remaining sprue is removed and the base plate may be handled.

After the teeth have been waxed up on the aluminium base and "tried-in" satisfactorily, the case is flasked and processing of the acrylic resin gum work is carried out in the usual way.

After the finished case is removed from the plaster, care must be taken to ensure that the anodized surface is not damaged whilst polishing the acrylic surface. (*Fig.* 4 shows a completed case.)

SUMMARY

The use of a commercial alloy of aluminium containing 5 per cent of magnesium for the construction of denture bases by a centrifugal casting technique is discussed.

The properties of this alloy are compared with those of other denture base materials and indications for its use are given.

The technical problems involved in the handling of this material are considered and details of the method of construction and the finishing of aluminium denture bases are presented.

Acknowledgements.—I wish to thank Professor H. B. Fenn for his encouragement and advice in the preparation of this paper. I am indebted to Mr. J. H. Cragg for the part he has played in developing the laboratory technique and to the British Aluminium Co. Ltd., and Foundry Services Ltd., for their technical assistance.

In conclusion I wish to express my gratitude to Miss B. Whiteley of the Department of Dental Photography and Miss D. Carter of the Department of Medical Illustration for the photographs and diagrams.

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Vinyl Ether

Although vinyl ether is extremely volatile and therefore difficult to give, there is a very high degree of safety as against ether or ethyl chloride administered with nitrous oxide and oxygen.

The disadvantages are that it decomposes rapidly when exposed to air, it is expensive, and it has a garlic-like smell which is very unpleasant. In spite of its disadvantages the safety in administration is very great, and there are no complications.—MASSEY DAWKINS, C. J. (1958), *Brit. med. J.*, **1**, 1116.

SILICATE CEMENTS: HOW TO SELECT AND USE THEM*

By **GEORGE C. PAFFENBARGER**, D.D.S., D.Sc., *Washington, D.C.*

DENTISTS know the shortcomings of silicate cement. The high solubility, low strength, extreme brittleness, high shrinkage, and acidic and irritating character of the cement are tolerated simply because no other material has a better combination of desirable attributes as a direct filling material for the front teeth. Therefore, the method of using silicate cement is all-important. The values for solubility, strength, shrinkage, and the amount of acidic products available for tissue irritation can be varied depending upon the method of using the cement. The demonstration of these effects in the laboratory and the transfer of these laboratory findings to clinical practice are the primary purpose of this report.

Composition and Its Effects

Powder.—The powders are complex aluminosilicates, usually fused with a fluoride containing flux (Matthews, 1935; Paffenbarger, Schoonover, and Souder, 1938). The fluorine-content is relatively high—ranging as high as 15 per cent by weight (Paffenbarger, Schoonover, and Souder). This high fluorine-content causes a silicate cement to etch glass. It probably accounts for the comparatively small amount of recurrent caries about silicate cement restorations (Volker, Bekaris, and Melillo, 1944) as silicate cement produces a considerable reduction in enamel solubility (Phillips and Swartz, 1957).

The glass-like powder is relatively insoluble in distilled water. In fact, it is about one half as soluble as powdered enamel in the same medium (Paffenbarger, Schoonover, and Souder).

Liquid.—The silicate cement liquids are aqueous solutions of phosphoric acid partially neutralized by the addition of aluminium or zinc salts or both (Paffenbarger, Schoonover, and Souder). The free phosphoric acid content will run from 35 to 47 per cent and have a *p*H of approximately 2. There is no such thing as a "neutralized" silicate cement liquid. Because of the high phosphoric acid-content, the silicate cement liquids gain or lose water depending on the humidity of the air to which they are exposed. This hygroscopic property of phosphoric acid is one of the factors that make the relative humidity of the air in which the cement is mixed of some importance.

Care of Powder and Liquid

The powder is stable in almost any climate. The chief precaution is to keep the bottle of powder tightly stoppered at all times, except when removing the powder for mixing. Slight contamination will make a perceptible colour change.

The liquid being susceptible to loss or gain of water should be protected from the air as much as possible. This means that (1) the stopper or cap should be in the bottle at all times except when actually withdrawing the liquid; (2) the liquid should not be placed on the glass mixing slab until just prior to beginning the mix; (3) the smallest possible area of the slab should be used in making the mix; and (4) ideally, the mixing should be done in a container which would protect the mix from the atmosphere (Grunewald, Dickson, Paffenbarger, and Schoonover, 1953).

Two methods of protecting the cement liquid from gain or loss of water due to atmospheric conditions are shown in *Fig.* 1. The saturated salt solution in the desiccating jar on the left must have a vapour pressure nearly the same as the silicate cement liquid. This will vary with the compositions of the liquid, so inquiry should be made to the manufacturer of the particular trade brand being used concerning the particular air humidity at which the vapour pressure of the cement liquid is in equilibrium. Different salts must be used depending upon

* A paper delivered to the American Dental Society of Europe, August 28, 1957.

the relative humidity desired. Standard chemical handbooks list the relative humidity over many salt solutions (*Handbook of Chemistry and Physics*). To maintain saturated solutions, there must always be some undissolved salt in the bottom of the desiccating jar.

Another suggestion is shown on the right of *Fig.* 1. Light liquid petrolatum, U.S.P., is added to the cement liquid. This spreads out into a thin film as shown in the illustration and effectively prevents changes in the water-content of the liquid.

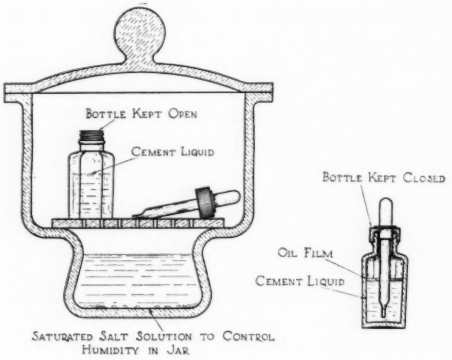

Fig. 1.—Two methods of protecting the cement liquid from loss or gain of water due to atmospheric conditions.

Microstructure of the Hardened Cement

Silicate cement powder is slowly dissolved in the cement liquid and in any practicable mix there is always powder in excess. Consequently, the hardened silicate cement appears in cross-section as shown in *Fig.* 2. The outline of the shape of the original powder particles can be seen. The cement liquid only attacked the surfaces of the larger particles. The product of this reaction between the cement liquid and the surface of the particles of powder is called the matrix. It is the substance that binds the undissolved powder particles together. It is the most soluble and weakly acidic portion of the hardened cement. The matrix is the part which shrinks, stains, and loses water in contact with air. Thus, the gel-like colloidal matrix, or the medium that cements the unused powder particles together, is the part that gives the silicate cement its undesirable properties. It is therefore important that the amount of matrix present in a mix of hardened cement should be kept minimal. This can be accomplished by a proper mixing technique.

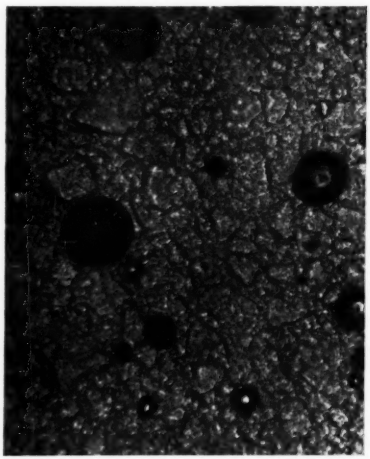

Fig. 2.—Cross-section of a hardened silicate cement. (The dark areas are bubbles of air, one defect caused by improper mixing.)

Technique of Mixing

Cold Slab.—The mixing slab should be chilled to just above its dew point. This retards the reaction between the powder and liquid during mixing. Thus, a larger amount of powder can be incorporated in a given quantity of liquid when the mix is made on a chilled rather than on a warm slab. If one makes the mix in a small rubber sack under cool water, then the maximum amount of powder can be incorporated regardless of atmospheric conditions.

Also, the mix should be made as rapidly as possible to minimize the formation of excess matrix. A mix can be made in 30 sec. with just a little practice. Longer mixing times increase solubility. The purpose of the mixing is to wet completely the powder surface with the liquid and to start the reaction between powder and liquid. As small an area of the slab as is practicable should be used to minimize exposing the hygroscopic unset

cement to the atmosphere. The mix should attain a heavy putty-like consistency. In short, one should make a thick mix on a cool slab as fast as possible. This will ensure the minimum amount of the matrix material which contributes to the most undesirable properties.

The dark circular areas in *Fig.* 2 are air-bubbles entrapped during the mixing of the cement.

Technique of Insertion

As soon as the mix is completed, it should be transferred to the cavity and the retaining or contouring strip should immediately be placed over it, drawn taut and held unvarying in this position until the cement has hardened. Do not guess at this time of hardening. Make the mix in excess and after insertion of the restoration hold the excess in the palm of one hand. Test its relative hardness by indenting with the finger-nail. When the cement cannot be indented, it has set hard enough to remove the strip. Make every attempt to judge the correct amount of cement to pack into the cavity so that the minimum amount of finishing will be required. After the strip is withdrawn, the filling should be coated with a grease such as petrolatum U.S.P., or preferably a silicone stopcock grease such as is used in technical laboratories. This grease is very tenacious and water repellent. The purpose of the coating is to keep the filling protected from saliva or air. In other words, the coating will preserve the water-content of the filling for a few hours after insertion. Some dentists prefer a low-melting paraffin wax as a coating. Wax is indeed an effective water barrier.

Technique of Polishing

None of the abrasives in the dental office will produce a surface as smooth as that left by the retaining strip. The lingual surface should require little or no finishing if the strip has been properly adjusted.

Polishing should be delayed for at least 24 hrs. as the cement is very weak just after the removal of the retaining strip. The data in *Table I* show how the strength of a silicate cement changes with time. The finest grit of cuttle-fish disks should be used slowly and should be covered with a grease so that the surface of the filling will be protected from the air. Under no circumstances should the filling be made flush with the enamel margin just after removal of the strip. To do so breaks off the edges of the weak silicate cement and makes a V-shaped ditch around the filling. Much of the damage to silicate cements is done by polishing prematurely.

Table I.—Change of Compressive Strength of a Silicate Cement with Time

Age of Specimens Time	*Compressive Strength lb. per sq. in.*
15 min.	10,000
1 hr.	12,000
3 hr.	15,000
1 d.	16,000
1 wk.	19,500
6 m.	22,500
14 m.	24,000

Care of Silicate Cement Filling

If the patient is a mouth breather, he should be instructed to coat his silicate fillings with petrolatum every night before retiring; otherwise the silicate cement restorations will last only a few months. The dentist should always protect any silicate cement fillings that he may isolate with rubber dam or cotton rolls by coating them with a grease, preferably a silicone stopcock grease.

Demonstration of the Effect of Technique upon Fillings in the Mouth

Laboratory data on silicate cements demonstrate the effect of technique upon the numerical values for pertinent chemical and physical properties such as setting time, solubility, strength, and shrinkage. These effects can likewise be demonstrated clinically.

In *Fig.* 3 are two adjacent silicate cement fillings made of the same cement, which show gross differences within even a few weeks of insertion (Paffenbarger, 1951). The good filling on the left was made from a mix spatulated for 30 sec. on a slab at 60° F. Petrolatum was placed on this filling just after the matrix strip was removed. Finishing was deferred for one week. The restoration on the right was made from a mix spatulated for 2 min. on a slab at 98° F. Moisture came in contact with the restoration after the matrix strip was removed.

Immediately thereafter, the restoration was dressed down flush with the enamel margins.

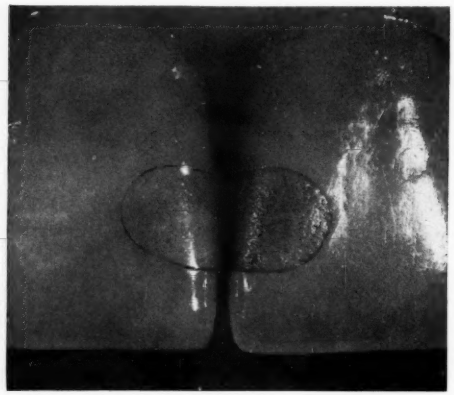

Fig. 3.—Silicate cement fillings made from the same cement but by proper techniques (left filling) and improper techniques (right filling).

The photograph (*Fig.* 3) was taken a few weeks after the fillings were inserted.

Conclusion

A silicate cement restoration may be either a work of art or a disappointment to the patient and the dentist. The difference can depend on the technique used in mixing, packing, and finishing the restoration. This can be demonstrated readily on controlled clinical tests constructed on the basis of data derived in the testing laboratory.

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BOOK REVIEWS

THE IMPACTED LOWER THIRD MOLAR. By WILLIAM E. DURBECK, A.B., D.D.S., Consultant, Robert B. Green Memorial Hospital, San Antonio, Texas; Civilian Consultant, Brooke Army Hospital, Ft. Sam Houston, Texas. Second edition. 9×6 in. Pp. 188+x, with 117 illustrations. 1958. London: Henry Kimpton. (Brooklyn, N.Y.: Dental Items of Interest Publishing Co. Inc.) 37s. 6d.

IN many books on dental and oral surgery the impacted third molar has its rightful place, but it is unusual for a book to appear which deals with such a tooth *in toto* and that is why it is such a welcome addition to dental literature. This book appeared in its first edition in 1943 and in the second one there is an additional chapter on subacute bacterial endocarditis, which emphasizes the necessity of eliciting a complete history of the patient who is going to have his impacted third molar extracted. Beginning with the chapter on general considerations the author deals with, in the succeeding eight chapters, anatomical considerations, clinical examination and pre-operative treatment, anæsthesia, general roentgen considerations, radiographic examinations, planning the procedure, technique of instrumentation, and post-operative care. In the actual operative technique the reader may find himself at variance with the author's suggestions. Nevertheless, the technique and instrumentation is dealt with on sound basic principles of planning the procedure. The book is fully illustrated, but it is unfortunate that the majority of the illustrations are of poor quality and poorly orientated. This is a minor criticism which should not deter the reader from the value of the book, which should be

in the hands of not only oral surgeons but general dental practitioners as well. This book will well repay careful study and can be heartily recommended.

H. M.

ORAL MICROBIOLOGY AND INFECTIOUS DISEASE. A Textbook for Students and Practitioners of Dentistry. By GEORGE W. BURNETT, B.A., M.A., D.D.S., Ph.D., F.A.C.D. Lieutenant Colonel, Dental Corps, U.S. Army; and HENRY W. SCHERP, B.S., M.S., Ph.D., Associate Professor of Bacteriology and Immunochemistry, University of Rochester, School of Medicine and Dentistry, Rochester. $10 \times 6\frac{1}{2}$ in. Pp. 589+xvi, with 257 illustrations. 1957. Baltimore: The Williams and Wilkins Co. (London: Baillière, Tindall & Cox Ltd.) 88s.

THIS book may be divided into three parts: the first part, besides including a section on the history of microbiology, covers the cultivation, cytology, and metabolism of bacteria, with an account of sterilization, chemotherapy, and serology. The second part deals with the bacteriology of caries, periodontal disease, pulpal and periapical infections, with chapters on those systemic diseases caused by micro-organisms and with oral manifestations. Lastly, there are descriptions of individual organisms and their associated diseases.

For those readers who already have a good knowledge of the subject, this very well-illustrated book should be most useful. Quite apart from the lucidity of description, it would be difficult to name another text where the bacteriological aspects of those diseases of immediate interest to the dental surgeon are dealt with in such a competent fashion. However, its suitability for use by undergraduates, except as a reference book, is another matter. The length of the book (589 pages) indicates its detail. An undergraduate, and indeed many postgraduates, would tend to be overwhelmed by the relatively detailed presentation, especially regarding chapters such as that on serology.

It would be fair to say that this is a very good book for a postgraduate specializing in this subject, but is not very suitable as a standard text for the undergraduate dental student in this country.

E. N.

ABSTRACTS FROM OTHER JOURNALS

Ethyl Chloride, Nitrous Oxide, and Oxygen Mixture

In answer to the question "I give a number of dental anæsthetics, chiefly to children, using a Mekesson Apparatus, with vinyl-ether in addition to nitrous oxide and oxygen for prolonged anæsthesia. I would prefer, however, to give ethyl chloride in the nitrous oxide and oxygen mixture, as in many ways this is safer and better than vinyl-ether or trichlorethylene. Is there any apparatus which can be incorporated with a Mekesson for delivering ethyl chloride by drip or by controlled addition to the mixture? Is there any objection to the idea of a nitrous oxide–oxygen mixture with ethyl chloride in an open circuit?"

The following answer is given:

"Ethyl chloride as a supplement to nitrous oxide and oxygen has been in use for a very long time. Within the last fifteen years serious interest in this combination has been revived. There is no commercially available vaporizer for ethyl chloride for the Mekesson apparatus, nor is there one for such British equipment as the Boyle or Walton. However, all that is necessary is a small hole in the circuit somewhere between the apparatus and patient into which ethyl chloride can be squirted. A drip vaporizer would need special precautions in its design owing to the low boiling-point of ethyl chloride. There is no objection to ethyl chloride being used in an 'open' circuit. Ethyl chloride is widely used, its main danger being overdose. Many anæsthetists, however, particularly in the United States, would not agree with the questioner that ethyl chloride 'is safer and better than vinyl ether or trichlorethylene'."—*Brit. med. J.* (1958), **1**, 236.

Fibrous Dysplasia of Maxilla and Mandible

A clinical, radiological, and histological study has been made of 69 cases of fibrous dysplasia of the maxilla and the mandible, seen at the Mayo Clinic.

It is an indolent tumefactive process of fibro-osseous character seen in patients between the ages of 10 and 30 years. It occurs more often in the maxilla of the female. The pathogenesis is obscure, but it is considered to be due to a developmental defect. Many fibro-osseous lesions fall within the scope of fibrous dysplasia, but conditions which can be separated by clinical, laboratory, and roentgenological criteria such as cementoma, osteoid osteoma, epulis with calcification, cherubism, brown tumours of hyperparathyroidism, and Paget's disease should not be classified under fibrous dysplasia. Chondromatous elements are rare in maxillary and mandibular fibrous dysplasia. If present, it is usually malignant. The treatment of choice in fibrous dysplasia of the jaws is conservative surgical intervention. Irradiation is of no value. Approximately 20 per cent of these tumours continue to grow after treatment, except for those radically excised.—ZIMMERMAN, D. C., DAHLIN, D. C., and STAFNE, E. C. (1958), *Oral Surg.*, **2**, 55.

Basic Principles of Endodontia and their Application to Selection and Treatment

The following list of ten basic principles applies to every endodontic case: (1) Treatment of pulp-involved teeth is attempted only on those patients interested in retaining their teeth. (2) The patient's health should be sufficiently good to withstand the demands of proper treatment. (3) The tooth must be accessible and anatomically operable. (4) The tooth must be restorable. (5) The tooth must be strategic in relation to the dentition as a whole. (6) Periodontal tissue surrounding the tooth should be within normal limits to ensure adequate healthy support following completion of endodontic treatment. (7) If traumatic occlusion is present it must be capable of being corrected. (8) Canals should be free from debris and dry before being filled. If surgery does not follow filling of the canals, the canals should be sterile as established by two successive negative cultures. (9) Canals should be sealed hermetically and neither be overfilled nor underfilled. The ideal filling will obliterate the canal at the cemento-dentine junction. (10) All areas denoting pathologic lesions must show evidence of repair on follow-up X-ray examinations.—CRAIN, E. L. (1958), *Northw. Dent.*, **37**, No. 1.

Severe Reactions to Antibiotics

The problem of reactions to antibiotics, especially penicillin, is an increasingly grave one. The survey covered a three-year period and included a study of approximately one-third of the general hospital beds available in the United States. A total of 2995 reactions were reported, 80 per cent of which were associated with the use of penicillin. In those cases where the reaction was sufficiently severe to be life threatening in degree, penicillin was a responsible agent in 84 per cent of the cases. Of the 901 penicillin cases 83 terminated fatally, giving a mortality rate of 9 per cent.

It is of interest to note that the number of reactions to penicillin when administered in capsule or oral form was numerically less than when administered in the injectable form.

The lesson to be learnt from this important study is that this wonderful group of life-saving drugs may also be life threatening if the patient has been sensitized to the drug previously. Therefore, they should not be used promiscuously. Instead, they should be used only when there is a true indication that they are of great importance to the patient's successful recovery. When used, the oral form is obviously the safest route of medication and should be used when at all possible. If injection of penicillin is required, adequate emergency 'know-how' drugs and equipment must be immediately available since the typical patient with an anaphylactoid reaction usually dies within a few minutes unless emergency treatment is administered immediately.—HANNY, F. A. (1958) *J. Mich. St. dent. Assoc.*, March, 45.

Class 2 Cavity Preparations for Amalgam

In a survey of 1000 failures of amalgam fillings it is estimated that about 85 per cent were due to improper cavity preparation with poor extension for prevention, the most common error; 60 per cent were due to faulty cavity preparation.

Class 2 cavity undoubtedly offers the greatest opportunity for error in preparation. The occlusal portion must be extended to include all developmental grooves. The pulpal floor should be flat and seated at least a millimetre beyond the dento-enamel junction, the buccal and lingual cavity wall should converge slightly towards the occlusal to give what is termed the inverted truncated cone form, while the caries-free approximal cavity wall should either be perpendicular to the pulpal floor or diverge slightly towards the occlusal in order to preclude the chance of undermining the intact proximal marginal ridge.

Amalgam has a very good crushing strength if there is sufficient bulk to the material, but frail feather-edged margins cannot be tolerated. A bevel must always be avoided on the margins of a cavity preparation for amalgam.

There are five very definite reasons for cutting the cavity walls in the manner described in the text, and these five reasons are: (1) Improved resistance form; (2) Improved retention form; (3) Reduced chance of establishing a feather-edged margin at the occluso-bucco-proximal and occluso-proximal point angles; (4) Conservation of more of the important marginal ridge of the tooth; (5) Placement of the gingivo-bucco-proximal and gingivo-linguo-proximal point angles in areas of relative immunity to caries. When both proximal surfaces of the tooth are involved with caries two class 2 cavities are prepared and are joined on the occlusal surface.

Regardless of the instruments employed, such as ultra-high-speed handpieces and drills, the principles of cavity preparation remain the same. The newly invented high-speed drills should be used with great consciousness and wisdom.—MOSTELLER, J. H. (1958), *Northw. Dent.*, **37**, No. 1.

More Aids to Endodontic Practice

The author gives a number of additional aids with the object of saving time and labour, and so making the practice of endodontics more pleasant and comfortable for the operator. Some aids are original. It is recommended that these aids be put into practice as soon as the opportunity permits.—GROSSMAN, L. I. (1958), *Oral Surg.*, **2**, 91.

A Precision and Biological Root Canal Filling Technique

A root canal can be underfilled, over-filled, filled exactly flush with the apical foramen, or filled level with the cemento-dentinal junction. The advantages and disadvantages of each are discussed and the latter type of filling is favoured by the author as it offers the best chance for the apex to seal itself with cementum.

The various methods of filling a root canal are enumerated—namely, Diffusion technique, Impregnation technique, Overfilling technique, Cement technique, and Condensation technique, and these are assessed by comparison with a list of stipulations for an ideal root filling. Objections are raised against each technique and in order to overcome these objections a new technique is proposed.

This consists of reaming only the dentinal part of the root canal. This is carefully done to the greatest diameter feasible, and using a depth gauge. The taper on a selected standard gutta-percha point is reduced by rolling between glass slabs. The point is tried in the canal and is considered satisfactory when it fits firmly in the canal stopping short of the cemento-dentinal junction by 0·5 mm. The point is then removed, moistened in chloroform to a depth of 0·5 mm., dipped into dentine dust, and pressed firmly into the canal, this time to the proper depth, i.e., to the cemento-dentinal junction.

The rest of the pulp chamber and canal is filled with a silver cement introduced with smooth branches and packed with thin accessory gutta-percha points. Of 451 root canals filled in this way the periapical tissues failed to regenerate in 5 only.—KUTTLER, YURY (1958), *J. Amer. dent. Assoc.*, **56**, 38.

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VOLUME VIII, Nos. 1—12 (SEPTEMBER, 1957—AUGUST, 1958)

THE DENTAL PRACTITIONER and DENTAL RECORD

VOL. VIII, NO. 12 AUGUST, 1958

Including the official reports of the British Society of Periodontology, the British Society for the Study of Orthodontics, the European Orthodontic Society, the Glasgow Odontological Society, the Liverpool and District Odontological Society, the North Staffordshire Society of Dental Surgeons, the Odonto-chirurgical Society of Scotland, and the Dental and Medical Society for the Study of Hypnosis

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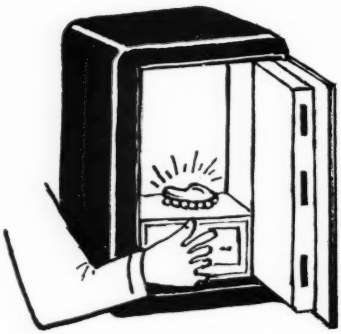

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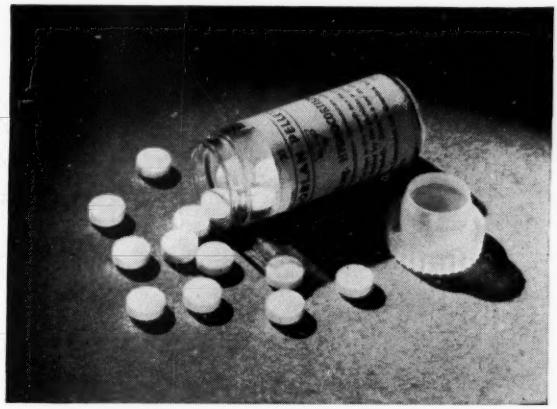

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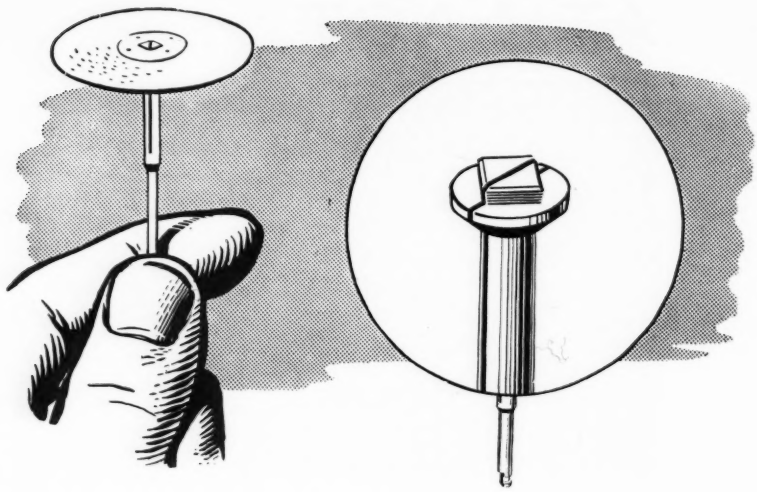

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References. 1. Gale, J. A., Dent. Record, 71, 15, 1951. 2. Henschel, C. J. and Lieber, L., Oral Surg. Oral Med. and Oral Path., 5, 155, 1952. 5. Lefkowitz, W. and Venti, V. I., Oral Surg. Oral Med. and Oral Path., 4, 1576, 1951.

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